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ABSTRACT

This paper summarizes the discussions of a workshop that brought together 74 neuroscientists, cognitive psychologists, education researchers and practitioners, and policymakers to explore the possible relevance to early childhood education and special education of recent developments in neuroscience and cognitive psychology. The report discusses: how neuroscience can help teachers teach; how educators can help guide brain research; and how neuroscientists and educators can help shape policy. Workshop presentations on brain development, language development, literacy development, and mathematics concept development are included as well as responses to the presentations. Workshop participants concluded that there is a chasm between what scientists accept as proven fact and what the public, teachers, and administrators believe. A number of recommendations for fostering communication and influencing policy are made, such as creating incentives and requirements for schools of education to understand, research, and expand teaching of early childhood development. Contains 21 references. (CR)

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Bridging the Gap Between Neuroscience and Education

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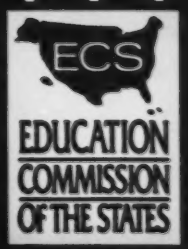

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Bridging the Gap Between Neuroscience and Education

Summary of a Workshop
Cosponsored by
Education Commission of the States
and
The Charles A. Dana Foundation

Held in Denver, Colorado
July 26-28, 1996

September 1996

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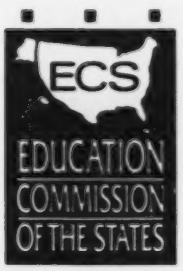

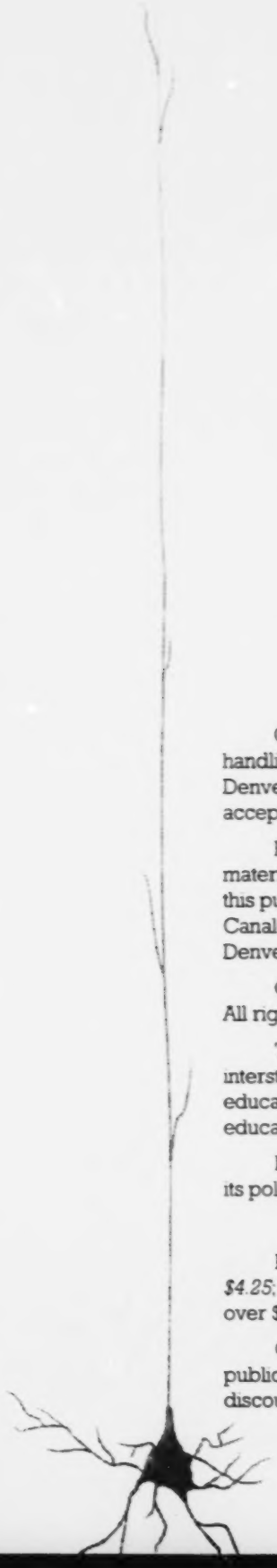

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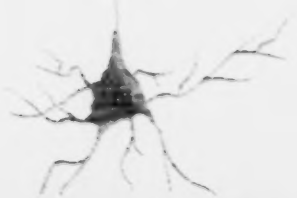

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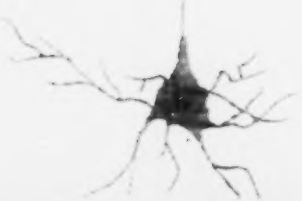


EXECUTIVE SUMMARY

Seventy-four neuroscientists, cognitive psychologists, education researchers and practitioners, and policymakers were invited to explore the possible relevance to schools of recent developments in neuroscience and cognitive psychology. This paper summarizes the July 1996 workshop cosponsored by the Education Commission of the States and the Charles A. Dana Foundation.

Every day scientists learn more about how a child's brain forms and develops. Every day teachers struggle to find effective tools for helping children use their brains to their greatest capacity. In a sense, both groups are focusing on different aspects of the same issues. It seems logical that science might offer some clues to guide educators — and that educators might ask questions that suggest fruitful areas for scientific inquiry.

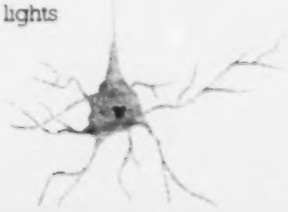
Oddly, discourse between the two groups has been virtually nonexistent. This workshop brought together noted researchers and practitioners in both fields for two days of exploration. Their charge: to determine whether neuroscience has information that educators can apply, and, if so, to suggest ways to bridge the historical communication gap between the two fields.

Neuroscience has provided fascinating glimpses into the brain's development and function. Scientists now believe the structures that control perception, action and cognition develop at the same time — not sequentially, as was previously believed. Babies are born with virtually a lifetime supply of nerve cells whose connections are established during the first five or six years of life. Although the number of nerve cells undergoes a continuous, gradual refinement and "pruning," the brain's ability to acquire new knowledge continues throughout a lifetime.

Even before birth, the infant's brain is constantly seeking to make sense of what it experiences, including the use of language. For instance, babies everywhere can distinguish the sounds of one language from another. But after about six months, babies begin to develop "magnets" that attract them to the sounds of their own language. They lose their early ability to discern fine differences in sounds in foreign languages. Those "perceptual maps" developed in infancy may account for distinctive national accents and the difficulty in learning and distinguishing related sounds in other languages as we grow older.

The brain has multiple memory systems that process and act on information in different ways. For example, short-term memory is formed in one part of the brain but must be transferred to another for long-term storage and retrieval. Different memory systems contribute differently to physical, intellectual and emotional activities.

Babies' sensory and emotional environments affect their development in profound ways that are only beginning to be understood. One study examined the effect of environment on very premature infants cared for in a newborn intensive-care unit. The nursery setting consisted of bright lights and mechanical background noise, with few voice sounds reaching



the infants. The infants who had little parental contact made fewer sounds than premature infants whose parents visited and spoke to them continuously.

Other factors affecting the brain's development include maternal drug, tobacco and alcohol use, pre- and postnatal infant and maternal nutrition, and early child care. Some of the brain's primary functions, such as vision, have critical development periods, which, if missed, will never occur. Whether critical periods exist for other functions such as language is not clear, but there at least may be sensitive periods — windows of opportunity when learning is easier. Science has not yet established whether secondary skills such as reading and math have critical or sensitive periods for acquisition.

What is clear, though, is that early stimulation helps a child develop. At the same time, while much of the brain's basic equipment is in place at birth and its neural connections continue to form during the first few years of life, a great deal of plasticity exists in its cognitive and intellectual development. Such findings suggest that an enriched home and school environment can help make the most of each child's mental capacities.

Children learn in different ways and display different types of intelligence, but conventional measures such as IQ address only one form of intelligence. There is neurological evidence that children are capable of learning more than is currently believed if information is presented in the manner best suited to each child's learning style. It is thus important to find ways to engage those special intelligences within an education system designed to maximize each child's opportunities to learn and to stop underestimating their capacity.

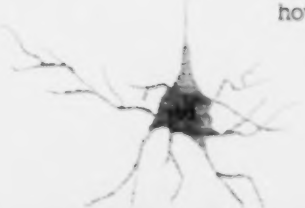
It is also important to provide multiple pathways for learning. For instance, children may learn to read more readily with a combination of phonics and whole-language instruction or grasp mathematics concepts and procedures better if they do both real-world math projects and rote-memory exercises.

Workshop participants concluded that neuroscientific findings probably do have implications for education, but there is a chasm between what scientists accept as proven fact and what the public, teachers and administrators believe. Neuroscience already has developed a good deal of well-substantiated information about how the brain develops and how language is acquired. Some of that existing information may be applicable to education, but the scientists urged the educators not to attempt to apply new research findings until further studies confirm and expand them. The group did agree, however, that collaborations between the two fields might yield practical information and suggest future avenues for investigation — perhaps on topics such as language acquisition that already have a widely accepted body of knowledge.

A number of recommendations for fostering communication and influencing policy arose from the discussions. Although there was not consensus on all points, some are listed here to spark discussion.

Communication

- Help educators, policymakers and the general public understand more about how the brain develops, what helps and hinders its progress, and how to accommodate different styles of learning.



- Develop ways of communicating scientific information to the media, public and policymakers that can be understood and acted on.
- Agree on common definitions for "learning," "memory," "critical periods" and other terms with multiple levels and interpretations.

Collaboration

- Identify specific areas of agreement among neuroscientists as a basis for collaborative studies; base projects on established principles, not on isolated results.
- Develop incentives and funding sources for sustained collaborative work by neuroscientists and educators.
- Find ways to expedite the translation of scientific research findings into educational practice.

Policy

- Undertake a major national study to develop special-education policy recommendations based on what is known about how children learn.
- Encourage state programs that address impediments to brain development, such as prenatal care, parental pre- and postnatal smoking, maternal diet and nutrition, and drug use.
- Reassess current education practices such as how and when foreign languages are presented.
- Create incentives and requirements for schools of education to understand, research and expand their teaching of early-childhood development.
- Upgrade the quality of child care and create standards for professional development of child-care workers.

Emerging knowledge of the brain holds enormous promise for improving the education of young children. It comes at a critical time. The increasingly technological society places high demands on the intellectual capacity of the workforce — and on the growing numbers of those persons excluded from it. Schools have not adequately addressed those needs. Continuing dialogue and collaboration among the groups assembled for this workshop, or among other individuals and groups, are steps in that direction.

INTRODUCTION

by Frank Newman, ECS President

Frank Newman
President
Education Commission of the States

This publication represents a major step in bringing forward what scientific research has learned about how the brain develops and how this bears on efforts to improve student achievement. While educators have known intuitively that the brain's structure and function play a critical role in the capacity to learn, the flow of new research findings over the last decade has provided new insights — often contradicting widespread assumptions about children and learning.

The workshop on which this publication is based brought together experts from the neurological sciences, cognitive psychology and education reform to talk about what each sector has learned that has implications for the others' work. Two broad research findings are of particular importance to policymakers and educators. First, contrary to the widely held view, children are not born with a fixed intelligence. Rather, at the time of birth, the brain and central nervous system are only partly "hard-wired." The infant's experiences — having someone talk to, sing to, read to or play with him or her — significantly influence development of the brain and nervous system connections that define the ability to learn. Second, in contrast, some experiences, including maternal smoking or malnutrition during pregnancy and infancy, can inhibit development of the capacity to learn.

These and other findings suggest that we need to radically revise many policies. Emphasis on the first years of life for all children is even more important than we previously thought. Such findings hold particular hope for improvements in early-childhood and special education if we can develop effective ways to address learning problems early.

The workshop did not provide cut-and-dried prescriptions for improving our schools; we did not expect it to. In fact, the neuroscientists warned that their findings are too tentative and isolated to serve as detailed roadmaps for how we structure schools. The broad outlines of the discussion, however, did show the possibilities of new and more productive approaches.

The workshop also provided a fascinating look at the possibilities and the potential for neuroscientists and educators to learn from one another. It also provided a forum for educators to share their concerns and needs with people doing the research on how children learn.

Much work remains to be done before many of these scientific results could be taken into the classroom. But if we can capitalize on what neuroscientists already know and accept, and if we can continue to work together, we will have a good beginning toward reaching that goal.

WORKSHOP REPORT: BRIDGING THE GAP BETWEEN NEUROSCIENCE AND EDUCATION

Seventy-four neuroscientists, cognitive psychologists, education researchers and practitioners, and policymakers were invited to explore the possible relevance to schools of recent developments in neuroscience and cognitive psychology. The workshop, cosponsored by the Education Commission of the States and the Charles A. Dana Foundation, began with brief presentations of selected findings in neuroscience, followed by responses from the educator's perspective. After the formal presentations, participants broke into four groups to discuss the issues in greater depth. A reporter from each group summarized the discussion for the entire gathering.

The second half of the workshop followed the same format, except education researchers gave the presentations and neuroscientists responded. Again, participants withdrew to their discussion groups and reported their observations. Finally, a panel moderated by Ray Suarez of National Public Radio considered how neuroscientists and educators can work together effectively to bring about needed policy changes. The workshop discussions form the basis for this report.

Ray Suarez
Host, *Talk of the Nation*
National Public Radio

Open a newspaper or switch on the evening news, and you may find a story about a promising advance in brain research — perhaps a clue to the effects of stress on the brain or a high-tech glimpse of a brain at work.

You are just as likely to find an item on sagging SAT scores or a commentary deploring the lack of preschool education for at-risk 4-year-olds.

Those recurring themes, and many related ones, are newsworthy in the United States because they have profound implications for society. Every revelation about how the brain operates, every insight that helps students learn, can contribute to a healthier, more productive future for all children.

With that in mind, would it be prudent for researchers and educators grappling with research protocols or curriculum challenges to shift their focus outward from time to time? Is there value in seeking answers — or perhaps reformulating questions — with the help of other disciplines that may be looking at different aspects of the same issues? Does neuroscience have a stake in the outcome of the education process? Can educators put to practical use some of the new findings showing how the brain develops? Can scientists and educators establish a dialogue that will enlighten both?

Those were some of the questions participants tackled during the July 1996 workshop in Denver, Colorado. Participants were invited to explore ways to connect early brain development to strategies for improving the education of young children. The two-day meeting was designed to lay the foundation for a continuing exchange of ideas and to spur joint research on early childhood education. To that end, the Dana Foundation announced a grant program offering seed money for planning efforts between educators and brain scientists.

Should we act now because there is so much profound new knowledge, or should we wait for that very reason?

— Lynn Kagan

How Can Neuroscience Help Teachers Teach?

Scientists have learned that the brain's "wiring diagram" starts to develop early in gestation. All parts of the brain develop in an integrated fashion over time, and a baby comes into the world with a nearly adult-sized brain that has most of its mental circuitry already in place. The task remaining is to solder the neural connections linking the cerebral structures. That process takes place at a rapid pace in the first five or so years of life, with the appearance of first steps, first words and other developmental milestones taking place within a well-established timetable, explained Patricia Goldman-Rakic, professor of neuroscience at Yale University School of Medicine.

Whether the brain is "hard-wired" or "plastic" — and whether plasticity includes the formation of new connections — is a topic of continuing debate in the neuroscientific community and stirred more discussion at the workshop. Goldman-Rakic is among those who believe the number of connections stabilizes by age 6, followed by a lifelong refinement process, including the strengthening of connections by experience. But development "goes on and on," she pointed out. "Most learning takes place after age 6; people acquire new knowledge and skills over a lifetime."

Research [findings in neuroscience] must surely have some implications for how we approach education. Now educators must tell us what they are.

— Patricia Goldman-Rakic

Some researchers believe new connections form as the result of this learning, noted Dee Dickinson, CEO of New Horizons for Learning. She cited several studies supporting the position that neural connections form throughout a lifetime. Therefore, it is essential to enhance opportunities for learning throughout life, not just during the first few years, she said.

Windows of Developmental Opportunity

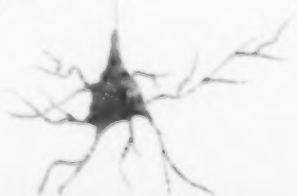
Scientists do agree that certain forms of learning are acquired with ease during various periods in a baby's development. Language is one such faculty. Patricia Kuhl, professor and chairwoman of the Department of Speech and Hearing Sciences at the University of Washington, reported that infants under 6 months of age respond with equal interest to the sounds of all languages, but quickly begin to develop a perceptual map that filters out fine distinctions among the sounds of other languages. That produces an interference effect which may account for the difficulty in learning languages in later life, Kuhl said.

Those findings, and the ease with which children in bilingual families acquire two languages, might lend credence to the argument that foreign-language instruction should begin in the early grades, not in high school or college. On the more volatile issue of bilingual education, do educators or policymakers have enough information from neuroscience to decide how to allocate funds to serve the foreign-born children entering American schools in such large numbers? The answer at this point is clearly no, the group agreed, but further research may help guide the solution.

We need to talk to the public and the press, but it's hard to get these difficult concepts across.

— Patricia K. Kuhl

Early experiences, without a doubt, help shape the brain. The brain's "wiring" and thus its potential for future learning are influenced by the sounds, sights and touch of the first few years of life. But is there a critical period for learning, when the brain must receive certain information before the window of opportunity closes? In some cases, the answer is "yes." Vision, for example, seems to have a critical period. Visual perception can be severely compromised or never will develop if the brain does not receive appropriate sensory input early in life.



Critical or sensitive periods also may exist for speech and basic numeric concepts, suggested David Geary, professor in the Department of Psychology, University of Missouri at Columbia. But some skills, which humans have used for just a fraction of the brain's evolutionary history, may be secondary and thus less sensitive to the time of presentation. "It may be irresponsible to speculate about critical periods for reading or math," Geary said.

Setting the stage for emotional and intellectual development also may have a critical or at least a sensitive period. Lucile Newman, professor of community health and anthropology at Brown University, reported that premature infants in her study whose parents visited them in the hospital nursery vocalized more and had fewer problems at age 6 than preemies whose parents stayed away.

At a minimum, development really wants to happen. It takes very impoverished environments to interfere with development because the biological system has evolved so that environment alone stimulates development.

— Steve Petersen

Other environmental factors such as diet, health and stress may also influence developmental outcomes, although researchers disagree about their importance. Jerome Kagan, professor of psychology at Harvard University, pointed out that not all cultures value early interaction with infants. Another participant cited the children of certain Guatemalan tribes who raise their infants in isolation to hide them from "the evil eye." Those children still develop language, as do Romanian orphans, for example, who are raised in extremely impoverished environments. "The relationship between stimulation and language acquisition isn't linear," Kagan noted.

"At a minimum," observed Steve Petersen, associate professor of neurology at Washington University Medical School, "development really wants to happen. It takes very impoverished environments to interfere with development because the biological system has evolved so that environment alone stimulates development."

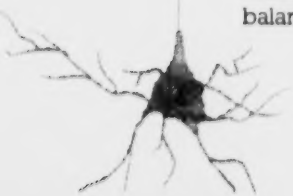
Additional research may help clarify the relationship between stimuli during early childhood and a child's intellectual and emotional development. Early childhood experiences may have greater bearing on a child's disposition and talents than is yet known.

The Memory/Learning Link

Memory and learning — and whether memory *is* learning — is another education concern that neuroscience is beginning to illuminate. At its most basic, learning is the process of acquiring memory, but complex neurological processes must take place to transfer newly acquired information to the long-term memory bank, where it can be stored for later use in novel ways. The brain actually has multiple memory systems (called by different names in various fields) that have specific roles.

For example, the motor-memory system comes into play for developing physical skills such as walking, golf or gymnastics, and the emotional-memory system has been shown to influence learning. The emerging literature on the effects on learning of stress, music and other stimuli may help educators provide environments that are more conducive to learning for normal and learning-disabled children alike.

How facts are acquired and applied has always been of concern to educators, and the education system is shifting from teaching children facts to teaching them to learn. At the same time, multiplication and spelling drills, the mainstay of rote-memory learning, may still have a place in a balanced education diet, some participants said.



Educators may find some guidance for this quandry in studies of how the brain processes different types of information. For example, if science could reveal whether different mechanisms are involved in acquiring "book learning" than in learning from experience, educators might be able to take advantage of such information in how they structure learning situations. Likewise, neuroscience may be able to shed some light on the phonics versus whole-language debate.

When facts or primary information are acquired is a concern of educators and parents alike. Early-childhood education has been defined generally as ages 3-6. Further elucidation of the critical/sensitive period calendar may suggest more attention is needed on the birth-to-age-3 period. Parents then assume an even more crucial role in an infant's intellectual and emotional development, with participants agreeing it is important to help involved parents "do more of what they're doing" and to help at-risk families do better.

New knowledge about how the brain grows and works poses a problem for educators, said Lynn Kagan, senior associate at the Yale University Bush Center: "Should we act now because there is so much profound new knowledge, or should we wait for that very reason?" Several participants cautioned educators to resist the temptation to adopt policies based on a single study reported in the newspapers or to use neuroscience as a propaganda tool to promote a pet program.

Educators and policymakers, as well as the public and the press, must take care to evaluate research findings in the context of a larger body of knowledge, they agreed. Moreover, the divergent environments of science and education further compound the problem of using scientific information: scientific research methodically addresses a single problem at a time to eliminate as many variables as possible, but education must deal simultaneously with many related issues. Peril awaits those who would tackle education's multidimensional challenges with one-dimensional tools.

As Joseph LeDoux, professor of neurology and psychology at New York University, put it: "There are no quick fixes. These ideas are very easy to sell to the public, but it's too easy to take them beyond their actual basis in science."

Other participants expressed concern about the popular conception of the brain as a computer. That image, said Lynn Arthur Steen, professor of mathematics at St. Olaf College, is highly misleading. "Thought is not the product of 'hard wiring.'" The brain-as-computer metaphor ignores the "uniquely human characteristics like consciousness and the capacity for self-reflection and learning from experience. The brain is not a computer to be programmed, nor a disk to be filled; it is an evolving ecosystem to be nourished," he said.

How Can Educators Help Guide Brain Research?

As a neuroscientist, Goldman-Rakic believes that understanding something about how the brain and its component structures develop can help educators understand readiness to learn. "The consistent timetable we have demonstrated through research must surely have some implications for how we approach education," she said. "Now educators must tell us what they are."

These ideas are very easy to sell to the public, but it's too easy to take them beyond their actual basis in science.

— Joseph LeDoux

The brain is not a computer to be programmed nor a disk to be filled; it is an evolving ecosystem to be nourished.

— Lynn Arthur Steen

Early childhood education is one area in which educators could take advantage of what neuroscience needs. Many early-childhood educators have known intuitively that children's capacities develop in tandem, and the findings of neuroscience seem to support education researchers' pleas for integrated, contextual instruction in mathematics, reading, spelling, science and so on. But individual variation is wide, and many children with dyslexia and learning disabilities, particularly in disadvantaged areas, need intensive, one-on-one instruction to learn to read, for example.

If neuroscience has strategies to improve what we're doing, we can put them in place very quickly for four million children.

— Robert Slavin

Similarly, children vary in their approaches to mathematical reasoning, and knowing something about how the brain processes numeric data may point to new ways to instill mathematical concepts. "If neuroscience has strategies to improve what we're doing, we can put them in place very quickly for four million children," said Robert Slavin, co-director of the Johns Hopkins Center for Research on the Education of Students Placed at Risk.

But educators haven't always asked for advice, and neuroscientific knowledge may be too isolated and tentative to date to have a strong impact on education. Participants agreed educators must be more assertive, however, in stating their needs to brain researchers. James McGaugh, director of the Center for Neurobiology, Learning and Memory at the University of California–Irvine, suggested that rather than waiting for neuroscientists to conduct research that may benefit them, educators should look to the model of NASA and the astronomers: "Here's what we want to know; how can you help us?"

Education researchers, reformers and local line educators have a vast reservoir of knowledge that is worthy of further investigation. "Neuroscience needs to take the intuitive knowledge of people in education whose experience might help us think about useful areas for research," Petersen said. That would open the door not only to research in basic science but also to joint studies that might have immediate practical application.

How can today's educators help tomorrow's neuroscientists?

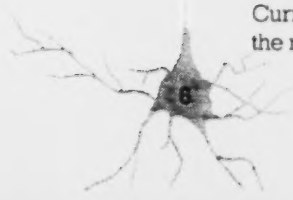
— Geoffrey Saxe

Geoffrey Saxe, professor in the Graduate School of Education and Information Studies at UCLA, had some ready questions for neuroscience: "Are children in traditional classrooms learning mathematics? How can we help teachers create an atmosphere that fosters conceptual mathematics understanding? In short, how can today's educators help tomorrow's neuroscientists?"

Steen wondered if neuroscience can cast some light on the relationships among factual mathematics knowledge (such as 5+6=11), procedural knowledge (long division) and understanding (place value). If those types of knowledge are acquired in different ways, educators may be able to devise better ways of helping children grasp mathematical concepts.

How Can Educators and Neuroscientists Continue This Dialogue?

Participants clearly agreed that the dialogue begun with this workshop should — in fact, *must* — continue. But making scientific information available to educators in usable form is still in the future. "We have no systematic means of disseminating knowledge," observed Ron Brandt, assistant executive director for the Association for Supervision and Curriculum Development. "We need to build a chain that links each step to the next in a natural, direct way."



But before communication can be natural and direct, those involved must agree on a common vocabulary. Throughout the sessions, many shades of meaning emerged for concepts such as memory, learning and critical periods. Until neuroscientists and educators understand one another's verbal shorthand, productive exchange will be difficult.

Participants also agreed that each discipline has a body of knowledge that has not been well cross-fertilized to other fields. Neuroscience has developed a good deal of well-substantiated information about how the brain develops and how language is acquired, and educators have long recognized certain developmental milestones.

"We know, for instance, that foreign languages must be learned in the first years of life to be learned well, but we don't have ways to take advantage of that knowledge," Brandt noted. "How should we plan so that children will learn the languages our society needs? Will technology reduce the need for people to know languages in the years ahead?"

How should we plan so that children will learn the languages our society needs? Will technology reduce the need for people to know languages in the years ahead?

— Ronald Brandt

Collaborations such as the Parents as Teachers National Center/Washington University School of Medicine three-year joint project (see page 21) might be one way to answer such questions. Educators with creative proposals for projects may find ultimately receptive — if initially skeptical — audiences.

"I won't say my proposal to the neuroscientists was an easy sell," said Mildred Winter, executive director of the Parents as Teachers National Center, "but eventually we developed a team of five neuroscientists who were willing to brainstorm with a team of parent educators." The educational tools developed for this project will use scientific information about the brain to help teen-aged mothers and single-parent families enrich their babies' early learning environments.

Potentially fertile fields for joint investigation include examining dyslexia from a neuroscientific perspective or focusing on a behavior, perhaps speech development, that involves multiple systems in the brain. Other interdisciplinary studies might explore critical periods or multiple memory systems to determine whether early-childhood education should focus on birth to age 3. Additional collaborations might seek ways to improve the success rate of special-education programs or resolve some recurring questions about bilingual education.

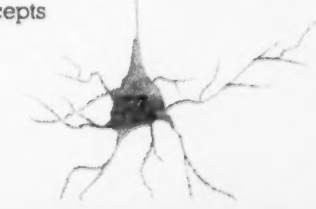
"Special education and children with disabilities are ripe for collaboration between neuroscientists and educators," said Donald Bailey, director of the Frank Porter Child Development Center at the University of North Carolina. "Since most disabilities have a neurological basis, neuroscience can help us understand how to modify instruction based on specific problems."

Special education and children with disabilities are ripe for collaboration between neuroscientists and educators.

— Donald Bailey

The public's hunger for knowledge behooves neuroscientists to learn to communicate outside of the academic community, participants agreed. Perhaps intermediaries can handle some of the tasks, suggested Frank Newman, Education Commission of the States president. The intermediaries should have expertise in both spheres and be able to translate and interpret important concepts in a way that could be acted on appropriately by parents or policymakers.

But there will be times when researchers must communicate directly with the public, i.e., through the news media. "We need to talk to the public and the press," Kuhl agreed, "but it's hard to get these difficult concepts across," especially when responding to reporters under deadline



pressure. Katherine Bick, consultant to the Charles A. Dana Foundation, urged fellow scientists not to be "overly critical of the few scientists who have learned to communicate with the public. Those who are good communicators shouldn't destroy their scientific reputations when they do it."

Whatever forms communication channels take, "we need to stimulate public discussions," said John Abbott, director of the Education 2000 Trust, "because the issue is not just science and education — it is learning and helping children. That concerns everybody."

The issue is not just science and education; it is learning and helping children. That concerns everybody.

— John Abbott

How Can Neuroscientists and Educators Help Shape Policy?

This gathering of neuroscientists and educators was not designed to result in policy recommendations. Rather, it was a first step at bringing the two groups together to talk about possibilities and needs. Much more communication and work are needed before neuroscience could have a strong impact on what happens in the classroom. Nevertheless, some education policy areas were pointed to as possible places in which neuroscience could aid public understanding.

Child care and youth policy itself are two examples. The United States, noted Edward Fiske, senior counsel for The Widemeyer Group, a Washington, D.C.-based public relations firm and former education editor of *The New York Times*, is the only industrialized nation with no national education policy and no policy concerning the care and development of young children. Thorny issues such as academic standards and whether early-childhood education should receive more attention than special education have not been effectively addressed at a national level, he said.

Nor has the United States addressed child-care standards. One participant commented that evolution has not designed humans to care for eight babies at one time, but infants and young children are routinely cared for in crowded day-care centers staffed by inadequately trained employees.

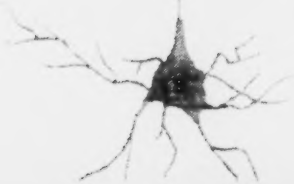
The United States is the only industrialized nation with no national education policy and no policy concerning the care and development of young children.

— Ted Fiske

Neuroscientists can contribute to the public's understanding of these and other issues and guide public opinion to influence education policy reform, participants noted. For example, enormous amounts of money are poured into special-education programs whose effectiveness is a subject of impassioned debate. As Bailey pointed out, "The real policy issue for special education may be . . . to define what we mean by 'individualized service for all children' and how we can work for every child's success." Findings in neuroscience could perhaps help policymakers set cost-effective yet compassionate goals for special education.

"Many legislators and governors are open to good advice," noted Uri Treisman, director of the Charles A. Dana Center for Mathematics and Science Education. "We must make sure we have mechanisms for giving advice to people who seek it. We are not as influential as we could be in saying how resources are spent."

But educators and scientists should be cautious about how they apply influence, said Steen. "Policy recommendations have little chance of survival unless they are well-connected to current reform movements such as those for standards, accountability or local control." They must be



backed by solid evidence and, once in place, acted on responsibly and effectively.

Kagan neatly summed up the policy discussion: "Social change comes from external forces and also from what happens internally. It is our job to define what we want children to accomplish."

The Brain Matters

If a single theme emerged from the conference, it was: *the brain matters.* It matters at the level of basic science, where researchers are painstakingly unlocking the mysteries of its structures and functions. It matters for cognitive psychologists, who are providing new insights into how and when children learn and whether there are critical or sensitive periods for acquiring certain higher-level functions. The brain matters for educators, so they can find ways to enrich the school experience for all children — the gifted, the creative, the learning disabled, the dyslexic, the "average" student and all the children whose capabilities are not captured by IQ or other conventional measures.

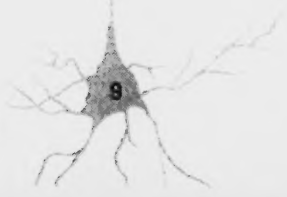
We are not as influential as we could be in saying how resources are spent.

— Uri Treisman

The brain matters to parents and caregivers, too, not just in common-sense issues such as protecting a child's head from injury. Parents also must understand how prenatal drug and alcohol use, maternal nutrition and early interaction with infants affect the developing brain before and after birth. The brain's sensitivity to early environmental influences also underscores the importance of adequate training for early-childhood educators and child-care workers.

The brain matters also for policymakers, who make the tough choices, and for school administrators who strive to squeeze just a little more service out of ever-shrinking budgets. Knowing how the brain develops may help them better focus their priorities.

The brain matters because children matter. How children learn and how they are taught matter, too. It is as simple — and as complex — as that.



INFORMING THE DEBATE: POINT/COUNTERPOINT

To provide a springboard for discussion, neuroscientists and educators briefed the group on developments and concerns in their respective fields. Each presentation was followed by a response from the other field's perspective. The following section summarizes these discussions.

Brain Development

What Can Neuroscience Contribute to Education?

Patricia Goldman-Rakic
Professor of Neuroscience
Yale University School of Medicine

We have learned through 15 years of research that structures in the brain that control perception, action and cognition develop at the same time. The brain's blueprint is drawn during the first half of gestation, and its developmental timetable and pathways aren't easily altered. Babies are born with most of the nerve cells — neurons — they'll ever have. The major connections — synapses — between those neurons are joined during the first five years of life, with fine tuning or pruning of the number of synapses continuing perhaps until puberty. The number of synapses remains stable through most of adult life and then gradually declines in old age.

While the child's brain acquires a tremendous amount of information during the early years, most learning takes place after synaptic formation stabilizes. From the time a child enters 1st grade, through high school, college and beyond, there is little change in the number of synapses. There is considerable debate within the field about whether learning creates new synapses — I haven't seen convincing evidence for that.

Contrary to what you may read in the popular press, the brain's structural and functional development is inseparable. No one area of the cerebral cortex — the part of the brain responsible for sensing, moving and thinking — develops earlier or faster than another. That doesn't mean that every system marches in lockstep with all the others, however. The brain's structures are linked by a complex network of interconnections, but each structure is a separate module that functions in parallel with the others. Scientists don't yet know precisely the connection between behavioral competence and the timetable of events in the brain.

Because learning and memory are important components of the education process, the study of memory is another area of neuroscience that may provide useful information for educators. Memory can be divided into two independent systems: short-term or associative memory (*knowing* facts) and long-term or working memory (*using* facts). Long-term memory relies on many parts of the brain. For example, spatial knowledge, object knowledge and word knowledge are stored in different parts of the cerebral cortex. Short-term memory, considered the cornerstone of cognition, shows a high correlation with

Patricia Goldman-Rakic
Professor of Neuroscience
Yale University School of Medicine

intelligence, although we do not yet know whether individual differences in achievement or problem-solving strategies reflect biological variations in brain function.

Neuroscientists have learned a good deal about how the brain develops and works. Much remains to be learned. We do know that every part of the cortex — motor, sensory and cognitive — develops from whole cloth. So it makes sense that knowing when a child's brain connections are set to learn the first words or take the first steps would be useful to parents, educators and policymakers. The consistent pattern and timetable we have demonstrated through neuroscientific research must surely have some implications for how we approach education. Now educators must tell us what those implications are.

Sharon Lynn Kagan
Senior Associate
The Yale University
Bush Center

Response

Sharon Lynn Kagan
Senior Associate
The Yale University Bush Center

We have learned from Dr. Goldman-Rakic that the brain develops in an integrated fashion over time. Babies don't talk one week, tie their shoes the next, and then work on their emotional development — they learn many skills at the same time. I suspect early-childhood educators have known all along that education needs to address multiple aspects of development simultaneously.

That finding undergirds the call for integrated education in mathematics, spelling, reading and science. It also calls for curriculum designers to build in connection and context and for policymakers to rethink the expendability of programs like music and physical education when budgets are tight. Beyond that, it demands that we take a hard look at how we're training teachers and what educational research is going to track.

But the importance of the findings goes beyond curriculum. I would like neuroscience to inform us about children's curiosity, their temperament, how they approach life, their tenacity at learning new tasks and other non-cognitive dimensions of the mind. All of this will have significant bearing on a more fundamental issue: the nature of education itself.

As soon as the American public understands that much of the neural wiring is in place before birth, I think there will inevitably be a new emphasis on early-childhood education for parents and for teachers. "Early childhood" has been defined as the period from birth to age 8; Dr. Goldman-Rakic's findings seem to narrow that window of opportunity to birth to age 3.

Dr. Goldman-Rakic touched on memory and learning, a two-part process of acquiring facts and using them effectively. Findings in neuroscience have immediate implications for higher-level thinking skills — abstract problem solving, inference, deduction and so on — the very issues we're being called on to address in education reform. Those same findings seem to suggest, however, that it may not be such a good idea to abandon all the old-fashioned rote memory training after all.

At the same time, we need to ask whether agility in rote-memory acquisition and conventional IQ tests are the only standards of excellence. We need to develop measures that accommodate creative thinkers

and conceptualizers and consider individual variations in learning style. Public education in America has been profoundly value-laden, driven much more by culture than by brain biology. Perhaps neuroscience can help us develop more inclusive standards.

I'm excited about the implications of neuroscience for our work, but I want to suggest some safeguards against applying scientific findings hastily or haphazardly. Let's ask whether we're applying generally accepted neuroscientific knowledge; does it apply to all children or only to some, and if it applies to all children, is it amenable to change? Equally important, how can we make sure that scientific information isn't put into practice until it has been thoroughly tested and confirmed? How can we be sure every child should read by age 2 or play Suzuki at 18 months?

We also need to define who should be teaching our children during those crucial formative years. How can we assure that child-care workers have the necessary education — and appropriate pay — to be entrusted with the early training of these pliable young minds?

Language Development

How Babies Map Their Native Languages

Patricia K. Kuhl
Professor and chairwoman
Department of Speech and
Hearing Sciences
University of Washington

From Arabic to Zulu, the sounds of language constantly bombard the brains of infants around the world. We know from our studies in Japan, Russia, Sweden, Finland and the United States that babies are born with a keen ability to distinguish among language sounds. These tiny master linguists are true citizens of the world.

Adults, on the other hand, can't readily separate similar sounds in a foreign language. That's why adult native Japanese speakers have great difficulty hearing the difference between *R* and *L* and native English speakers can't tell a *B* sound from a *V* sound in Spanish. What happens to turn off the young child's ability to absorb the sounds of many languages?

Within their first six months, infants develop "language magnets" that attract their ears to the sounds of their native languages. For instance, the vowel sounds *ah*, *ee* and *oo* occur in every language in the world, but not always in the same form. Babies are born with an ability to distinguish among all vowel sounds, but if a sound doesn't occur in the baby's language, the ability to discern it will decline. For example, a baby who listens to Swedish, with its 16 vowel sounds, will have different language magnets than a baby who hears English, with eight or nine, or Japanese, with only five vowel sounds. The Swedish baby retains all the distinctions, but American and Japanese babies lose the ability to distinguish those vowels because their languages do not contain those sounds. The American and Japanese babies' developing magnets pull sounds that were once distinct into a single category of similar sounds.

Babies learn to categorize their languages' specific vowel sounds simply by listening to their parents' speech. At six months, even before they can produce and understand words, infants' perceptual systems are

Patricia K. Kuhl
Professor and Chairwoman
Department of Speech
and Hearing Sciences
University of Washington

configured to acquire their native languages. They have develc ed an adult ability to ignore fine differences in instances of the sounds and lump them into a single category. Imagine how well "wired" babies must be after a year of exposure to their language. That wiring, or perceptual map, accounts for the indelible accents that signal our national and regional origins.

The perceptual map accounts for our difficulty in acquiring new languages after we leave childhood. I think our language acquisition mechanism doesn't turn off, but rather becomes highly structured, creating an interference effect. It forces our minds to push new sounds through the linguistic maps or filters we developed in infancy. The filters for Japanese and American adults listening to the same *R/L* stimulus are totally opposite: Americans hear all *R*s clustered in a group and all *L*s in another group, separated by a wide perceptual space. The Japanese adult, on the other hand, hears the sounds in a single cluster and struggles with the distinction even after many years of speaking English. Current research in second-language learning suggests that students learn faster and better when multiple speakers repeatedly demonstrate the new language.

These findings have important implications for educators, policymakers and parents. First, they underscore the role of the parent or caretaker, who provides essential early input during the crucial birth to age 3 timeframe. How can we help them develop their infants' potential?

Second, they challenge the practice of teaching foreign languages in college and even high school. They suggest that languages should be taught in preschool, when children can readily master two languages simultaneously. Perhaps the ideal situation would be to learn two languages from infancy in a household with a native speaker of each.

Third, we must find out how language learning is altered in the developmentally disabled or in children with dyslexia and autism. Mapping is apparently inadequate in people whose cognitive or perceptual problems keep them from distinguishing sounds. Can we help them learn?

Finally, are we devoting enough resources to develop the mental capacities of the next generation? We must drive home this message — stimulation helps, lack of stimulation hurts.

Lucile Newman
Professor of Community Health and Anthropology
Brown University

Response

Lucile Newman
Professor of Community Health and Anthropology
Brown University

Dr. Kuhl's studies of "perceptual maps" suggest that infants hear the range of sounds in their native languages, probably even before they are born. What might that mean for infants born two to three months prematurely who spend what is essentially a prenatal period in a hospital incubator?

Preemies' environment in the nursery is clearly very different from their warm, dark uterine cocoon. These infants are exposed to bright lights and mechanical background noises. They are mostly alone and hear few voices, unless someone speaks directly into the incubator. To talk to their babies, visiting parents must speak through the incubator's openings.

Already underweight at birth, these very premature infants lose weight during their first weeks of life. Many parents, disturbed by what appears to be a loss of ground, become discouraged. Some give up. As one parent said, "I'll get to know him if he comes home."

Our study looked at low-birthweight infants' auditory environment to determine how often they vocalized, how parents interacted with their babies and how the infants responded. The parents of half of the infants visited infrequently or not at all. Most of those babies didn't increase their vocalizing during their first three weeks in the nursery, and some vocalized less by the third week. But infants whose parents visited regularly vocalized twice as much in the third week as in the first. What is the import for the developing perceptual maps of those isolated infants who heard so little speech during their first months of life?

This morning's speakers have emphasized the effectiveness of early stimulation in developing the cognitive capacity of young children, and my studies of premature infants confirm the basic argument that early stimulation is essential to normal development.

The development of the brain and central nervous system can be impeded in other ways, as well. Our best estimate is that 12% of infants born in this country suffer significant reduction of their cognitive ability as a result of preterm birth, smoking, alcohol or drug use in pregnancy, maternal and infant malnutrition, and postbirth lead poisoning or child abuse. While smoking and alcohol occur throughout the population, there is a much greater incidence in poverty areas. Parents and society clearly can help or hinder the cognitive capacity of every individual.

Today's presentations suggest a reemphasis on birth to age 3, particularly for those at risk. It is important to prevent risks of learning impairment from prenatal smoking, drugs or alcohol use. Particular attention must be directed to prenatal care, early child care and extension of other care programs like early family support, educational day care, Parents as Teachers, and Family and Work. But now that more working parents must have their children cared for by others who may lack both education and training, society is moving in the opposite direction. We must make sure society and parents clearly understand this bottom-line concept: it matters what you do.

Literacy Development

What Does Education Want from Neuroscience?

Robert Slavin
Co-director
Center for Research on the Education of Students Placed at Risk
Johns Hopkins University

Robert Slavin
Co-director
Center for Research on the Education of Students Placed at Risk
Johns Hopkins University

What education reformers want from neuroscience is good advice. We are always looking for ways to solve intractable problems like overall quality of instruction and dealing with the small number of children who are not reading despite good-quality education, effective family support services and individual tutoring.

Reading is a complex act. It involves developing fluent and automatic decoding, generic comprehension skills and strategies, meta-cognitive strategies for being aware of your

own comprehension, strategies for assessing and filling in gaps in your comprehension and study skills and, finally, developing a pleasure in reading. These and many other components of learning to read would probably map back to a different area of brain function.

We already know that children vary widely in their normal progression in reading. The "natural readers" read well regardless of instructional approach — you can hardly keep them from reading. Any approach works for them, no matter how unconventional. "Teachable readers," the greatest number of children, read well only if given high-quality instruction. They might have succeeded with an adequate basis in phonics. "Tutorable readers" can read well only when given high-quality instruction *and* high-quality individual tutoring. I think this group comprises the vast majority of children we call "learning disabled."

Where we need the most help from neuroscience is for the final category: the true dyslexics — children who won't learn to read even with high-quality tutoring. I think this group offers the greatest potential for genuine breakthroughs.

Let's assume that the "easy" problems like curriculum, instruction, family support, behavior problems, poverty and so on are taken care of. For the nondyslexic groups, we need a lot of information. For the teachable reader, we want your help in identifying the normal processes in learning to read. We want to know about the role of phonics, automaticity, transfer of learning. We want to help children apply knowledge from one area to another so they can solve more complex problems.

For the tutorable reader, we want to understand something about brain function that can be used to assess the needs of a specific child. That would be very useful in designing a focused tutoring approach.

Help us understand precursors to reading in younger children so we can design strategies that are not reading itself but that help children become more successful readers when they enter school.

Help us see the links between all forms of development and our educational objectives. Help us devise approaches to teaching that take us beyond the traditional styles that have limited us for so long.

Ultimately, educators and educational researchers are going to have to solve these problems, but we can benefit enormously from the hints and directions we get from research on brain science. If you have strategies to improve what we're doing, we can put them in place very quickly for about four million children.

Joseph LeDoux
Professor of Neurology
and Psychology
Center for Neuroscience
New York University

Response

Joseph LeDoux
Professor of Neurology and
Psychology
New York University Center for
Neuroscience

Learning and memory is one area of neuroscience that has accumulated a systematic body of knowledge.

Learning and memory. I think we all agree that learning is part of memory — it may be one-trial learning, but it is still learning. You might say that learning is the process of acquiring the memory. Learning is what happens when information is presented; memory

is the gradual process of manipulating that information into a form it will maintain over time so that it can be consciously retrieved and applied. I think neuroscientists and psychologists need to get back to basic issues about learning. We need to focus on the way the brain learns. If there's no learning, there's no memory, and therefore, there is no literacy.

Hard-wired vs. plastic systems. All learning and memory systems have an element of plasticity by nature's design. We need to consider the environmental factors that influence how hard-wired systems develop, such as poor diet, stress, disease and exposure to information at the right developmental period.

Individual differences. In most behavioral/cognitive experiments on learning and memory, we apply statistical methods to throw out the extreme examples, the animals that don't learn. There may be value in trying to figure out what individual differences keep those animals from learning.

Multiple memory systems. Humans have multiple memory systems: the declarative system, which makes possible conscious memory; the ability to pull information out of the memory banks and apply it in flexible ways; an emotional system which in some ways operates independently but can influence operation of the declarative system; and systems that deal with learning motor skills. All are important in developing literacy.

Systems vs. structures. No structure in the brain is an island. Each performs its function as part of a system.

Human vs. animal. The most detailed information we have about how the brain works comes from animals. Obviously, humans have some capacities that animals don't, such as language, mathematics and music. If we cannot address those issues in animal studies, should we approach them at the level of detailed neurobiology, or must we rely on studies of language, scavenging what we can from studies of other kinds of systems?

Memory vs. behavior. We tend to think of memory as information we have access to, but that's not always so. Our research has shown that patterns of activity persist in the brain, even when a behavior such as fear is no longer being expressed. We have seen that when learning increases activity in one cell, it also increases the relationships among cells, forming "cell assemblies" which we believe hold memories. These cell assemblies may fire spontaneously, without receiving a stimulus. In other words, the circuit initiates its own activity, which may shed light on phobias and other unconscious behaviors.

These ideas are still speculative, but they do show how techniques in neuroscience can give new insights into how the brain holds memory, even when the memory is not expressed in action.

How can brain research help educators? I'll end with a word of caution: we must be careful about applying isolated facts from neuroscience to an issue in education. First, make sure they *are* facts and that they fit into the context of a larger body of knowledge. Then apply the whole body of knowledge so that each piece of information is constrained by other information; that way, we'll have the needed checks and balances.

Geoffrey Saxe
Professor, Graduate School of Education and Information Studies
University of California at Los Angeles

Mathematics Concept Development

Are Children Learning Mathematics?

Geoffrey Saxe
Professor, Graduate School of Education and Information Studies
University of California
at Los Angeles

Procedures — steps taken to accomplish a goal — are often linked to culture. Counting, for example, is a simple numeric procedure for which a Papua New Guinea tribe has developed a system based on the human body. Their counting system consists of 27 body parts starting from the thumb of one hand, progressing up around the upper body to the little finger of the opposite hand. The tribe has no number words, so they gesture toward the body part representing that number — the bicep is 9, for example.

In contrast, English-speaking peoples have evolved a very different way to count. Our system involves using words to describe numbers; the English language has many number words that children by age 2 or 3 use to count objects. Children apply a one-to-one correspondence with objects but give special status to the last number in a set — for example, calling a group of five objects "five."

Children learn many other procedures, such as how to multiply, divide and do fractions. They are also taught conceptual operations that give mathematical meaning to the procedures they learn. For example, if a child of 4 or 5 is asked to make the second object in a row number *4*, he will count the first as *1*, skip to the third for *2*, call the fourth *3*, come back to identify the second as *4*, then jump to the end to call the fifth object *5*. The child has grasped the concept of how one-to-one correspondence should alter his counting procedure.

These conceptual operations are really a form of sense-making, and their organization shifts as they develop. If 4th-, 5th- or 6th-graders are asked to write a fraction showing how much of the drawing is gray, some children will write *1*. Those children are interpreting the fraction as a whole number. Other children will write *1/6*, meaning they understand fractions as the relationship among parts. Still others will view it as a part/whole relationship, writing the number *1/7*, not appreciating the square as a continuous quantity. Each of those ways of making sense of this fraction has some internal coherence. This demonstration makes it clear that procedures can be quite separate from conceptual operations, and developmental psychologists are trying to understand how the organization of mathematical thinking shifts over time.

Here are some questions for neuroscientists that I think are relevant to instruction as well as to discussions of neuroscience in education. Is it reasonable to ask whether children in traditional classrooms are learning mathematics? Is procedural knowledge, so often the staple of mathematics instruction, recognized as mathematics from a neuroscientist's perspective? If not, then how can we help children develop conceptual knowledge in mathematics?

If conceptual knowledge should be our focus, what kinds of professional development programs do we need for teachers and administrators? How can we help teachers create classrooms in which children make conceptual advances in mathematics?

I would welcome information about studies in neuroscience that will inform our understanding of what enhances, what limits and what supports both procedural and conceptual mastery in children. I also would welcome your thoughts on how neuroscience now and in the future can benefit from our knowledge of and research into children's mathematical education. How can we help you?

Response

David Geary
Professor
Department of Psychology
University of Missouri at Columbia

The first step in bridging the gap between neuroscience and education is to find a conceptual framework that will link neuroscience, psychology and education. Let us step back from learning mathematics and reading, then, and consider the possibility that evolutionary psychology might provide that broader foundation.

At the most general level, human behavioral, brain, cognitive, motivational and emotional systems are designed by natural selection to achieve some level of control over the environment. Cognition is part of a functional system that links important evolutionary goals with the environment in which those goals must be attained. The achievement of evolved or primary goals requires domain-specific procedural competence (behaviors that act on the environment), conceptual competence (knowledge of the domain constrains procedural competence) and application competence (knowing when and where procedures are best used).

There is a crucial distinction, however, between what I call biologically primary and secondary cognitive abilities. It appears that children are prepared emotionally, motivationally, cognitively and neurobiologically to acquire biologically primary competencies. Examples are language and other forms of social cognition, along with gauging the physical and biological environment. There also appears to be a biologically primary numeric competence that includes a basic understanding of counting, addition and subtraction. Primates and other species also have this basic numeric competence, but it appears to be limited to quantities of four or fewer.

These primary competencies are initially skeletal — that is, just the basic procedures, concepts and implicit understanding of where and when to use the knowledge are present. Learning develops more fully as children are exposed to their environment. Children are biologically motivated to seek out situations, often through play, that help develop their primary competencies such as language and social skills.

But much of what children learn in school is biologically *secondary*. Children do not appear to be compelled by biology to learn what they need to learn to function in a technologically complex society like ours. They are primed to acquire language and basic skills, but not to learn to read and solve

David Geary
Professor, Department of Psychology
University of Missouri at Columbia

complex arithmetic problems. Strong cultural support is needed to help children learn those secondary skills.

I believe the task for researchers and educators is to better understand:

1. How those primary competencies can be modified and used to acquire skills such as reading, writing and complex arithmetic.
2. How our natural modes of understanding the world can facilitate or impede learning in the classroom. For example, people base risk judgments on easily remembered examples such as airplane crashes rather than use more powerful statistical methods. This primary memory-based strategy may interfere with learning and using school-taught statistics.
3. How family, community and cultural factors influence the motivation to learn secondary skills.
4. How we determine the critical or sensitive periods — if they exist — for acquiring primary abilities. The concept of sensitive periods makes sense for primary abilities because it allows for an open system that can adapt these abilities to local situations. Are there sensitive periods for secondary skills like mathematics or writing? We don't know; in fact, it may be irresponsible to speculate about critical periods for those types of skills.

These are areas where cross-disciplinary exploration may be fruitful. We need to know what emerges in school and what doesn't; we need to know what qualities are continuous across human cultures and which are not; we need to know what works for most or all kids, not the 10% or so who pick up secondary skills without much effort.

Collaboration in Action: Parents as Teachers/Washington University Joint Project

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Editor's Note: The Parents as Teachers program described here is an example of a recent collaborative effort between educators and neuroscientists. The collaborative is funded by The Dana Foundation.

Parents as Teachers (PAT) is a parent-education/family-support program to help families give their children the best possible start in life. Our service to parents begins prenatally or at birth. Founded in 1981 as a single pilot effort in St. Louis, Missouri,PAT now encompasses 2,000 sites across the country. Our growth demonstrates that parents are hungry for guidance in the challenging task of rearing a young child.

The three-year collaboration between the Parents as Teachers National Center and the Washington University Medical School Division of Neuropsychology hopes to translate research findings on pre- and postnatal development into information that will help parents improve their child-rearing practices. For this project, supported by the Charles A. Dana Foundation, we will devote 18 months to preparation, then deliver services to 160 young families for the remaining 18 months of the study period.

Our first task will be to identify up to 10 important — but not cutting-edge — developments in neuroscience that may be useful to parents. We want to use well-established findings relevant to the issues the program wants to address, such as how memory relates to learning and the critical-period concept.

During the first phase, we will develop scripts and audiovisual materials for the parent educators and the treatment group, who will be selected from parents enrolled in the PAT program. We are looking for mothers who are likely to experience stress in parenting, such as pregnant teens in their third trimester who are still in school and single adult parents who have less than a high school education or who are on public assistance. In keeping with our philosophy of universal access, we will also select single parents who are neither undereducated nor on public assistance. The control group, also PAT enrollees, will receive our standard program. We also will develop tools to measure the program's effectiveness.

Dr. Patricia Kuhl from the University of Seattle and Dr. Carla Schatz from the University of California at Berkeley will serve as external advisors throughout the project, and Dr. Michael Strube of Washington University will develop and test the measurement tools for reliability and validity.

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NEXT STEPS

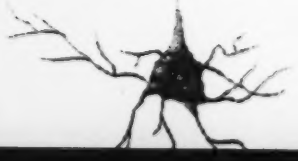
Throughout the two-day workshop, the neuroscientists and educators gained a deeper understanding of one another's concerns and constraints. They intuitively saw important implications of brain research for education, but concurred that sustained collaborative work is needed before those results can be taken into the classroom. Suggestions from the group and various individuals are listed below to serve as a starting point for discussion. They do not represent a consensus among participants.

Communication

- Help educators, policymakers and the general public understand more about how the brain develops, what helps and hinders its progress, and how to accommodate different styles of learning.
- Build pathways through a journal, newsletter or World Wide Web page devoted to communication among the disciplines.
- Help parents learn how to stimulate their children's cognitive growth.
- Develop more effective ways of communicating with the press, public and policymakers in a way that can be understood and acted on. Find ways to translate knowledge into a form usable by education institutions.
- Agree on common definitions for "learning," "memory," "critical periods" and other terms with multiple levels and interpretations.

Collaboration

- Convene public policy conferences of research synthesizers, education developers and policymakers to reassess current education practices, such as how and when foreign languages are presented or the care and education of children before birth through age 6.
- Identify specific areas of agreement among neuroscientists as a basis for collaborative studies — base projects on established principles, not on isolated results. Two initial common denominators might be critical periods and multiple memory systems, both of which have considerable relevance to education.
- Develop incentives and funding sources for sustained collaborative work by neuroscientists and educators.
- Identify critical areas for early learning. For example, should inherent capacities such as speech, language, movement and emotional development receive more attention than learned skills such as mathematics and reading?
- Find ways to expedite the translation of scientific research results into educational practice.



Policy

- Undertake a major national study to develop special-education policy recommendations.
- Encourage state programs that address impediments to brain development, such as prenatal care, parental pre- and postnatal smoking, maternal diet and nutrition, and drug use.
- Create incentives and requirements for schools of education to understand, research, and teach early-childhood development in new ways, for example, via modern biology-based curriculum.
- Find ways to focus resources on birth to age 6.
- Upgrade the quality of child care and create standards for professional development of child-care workers.
- Require states and school districts to set clear standards built on existing knowledge and recognition of their students' untapped potential.

FOR FURTHER READING . . .

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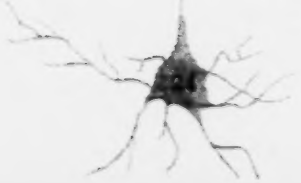

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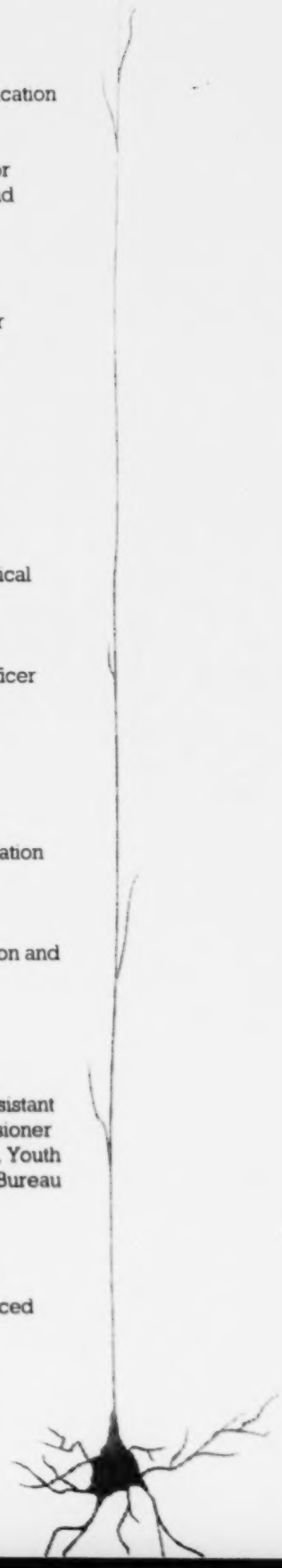

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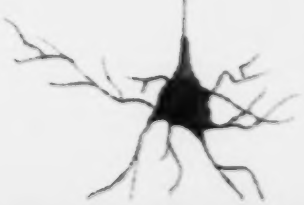

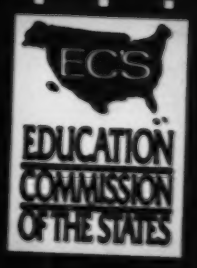

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